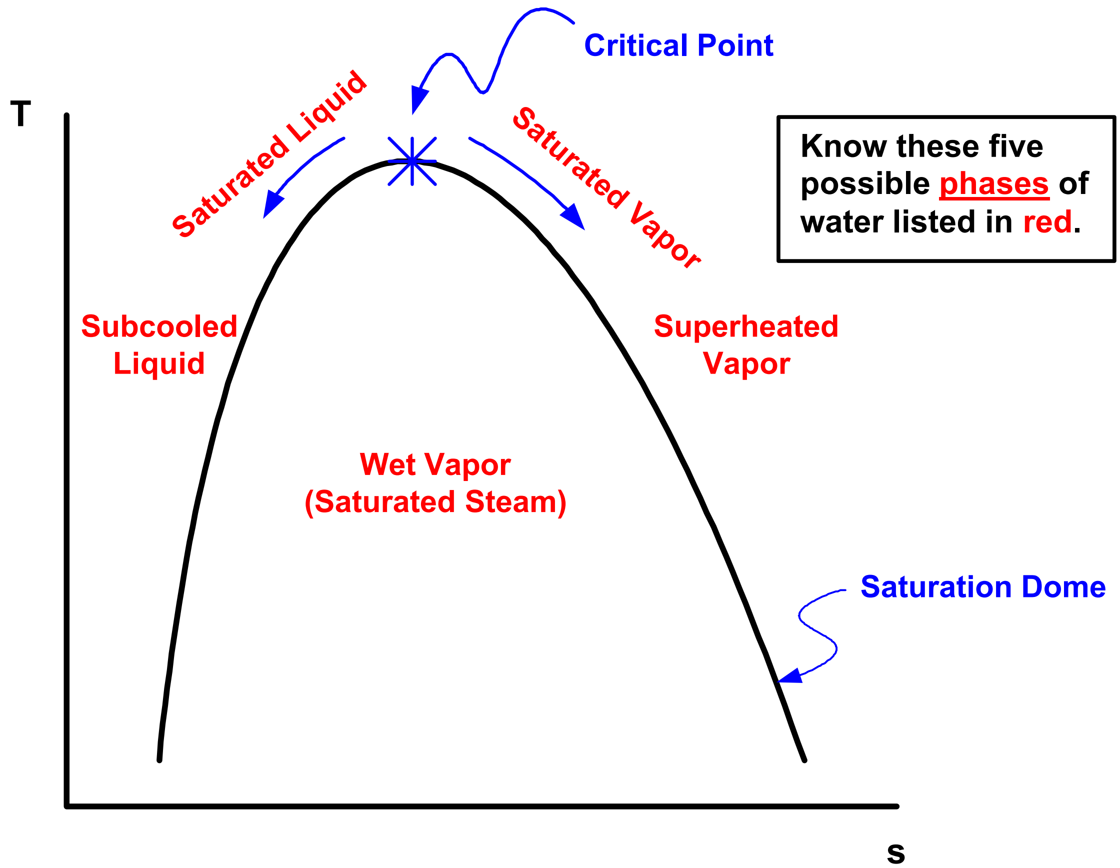
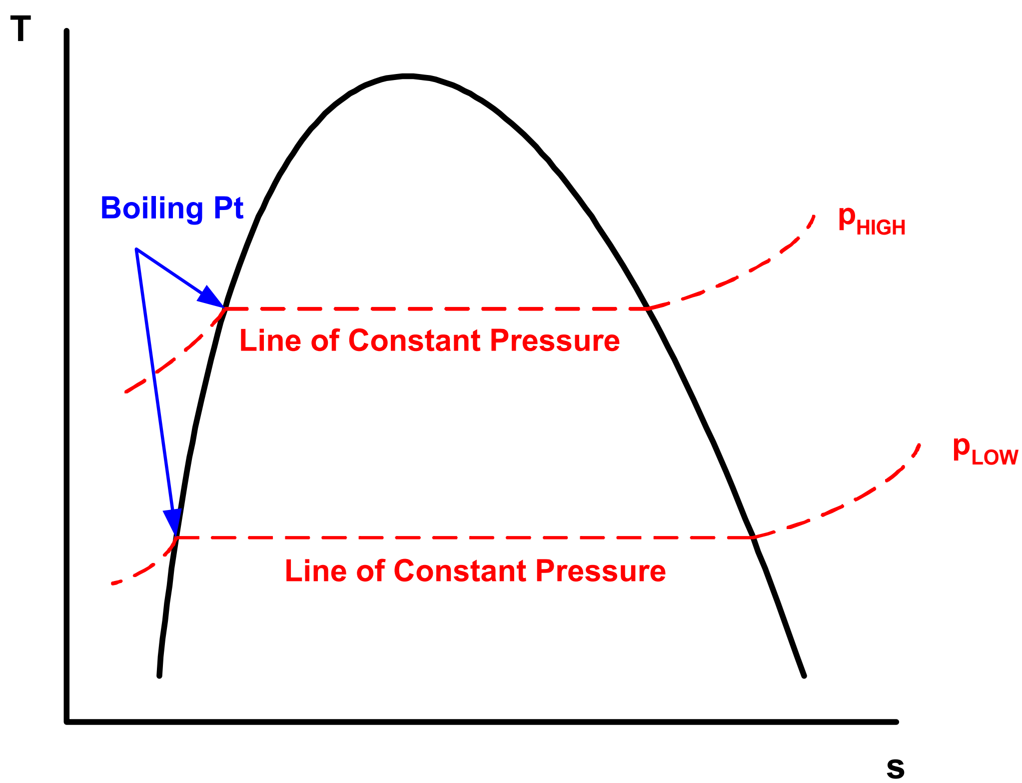
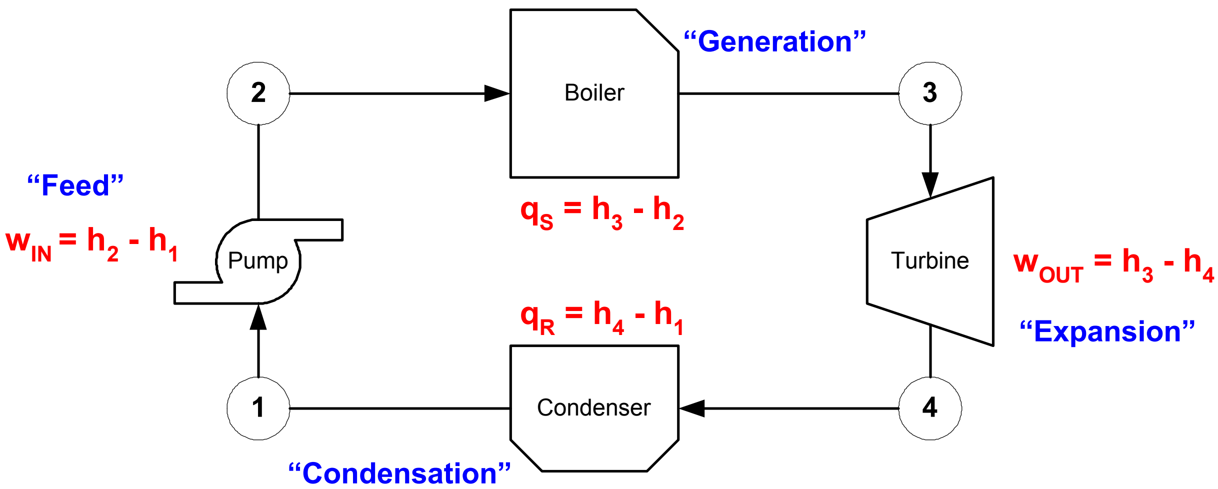
Steam Dome

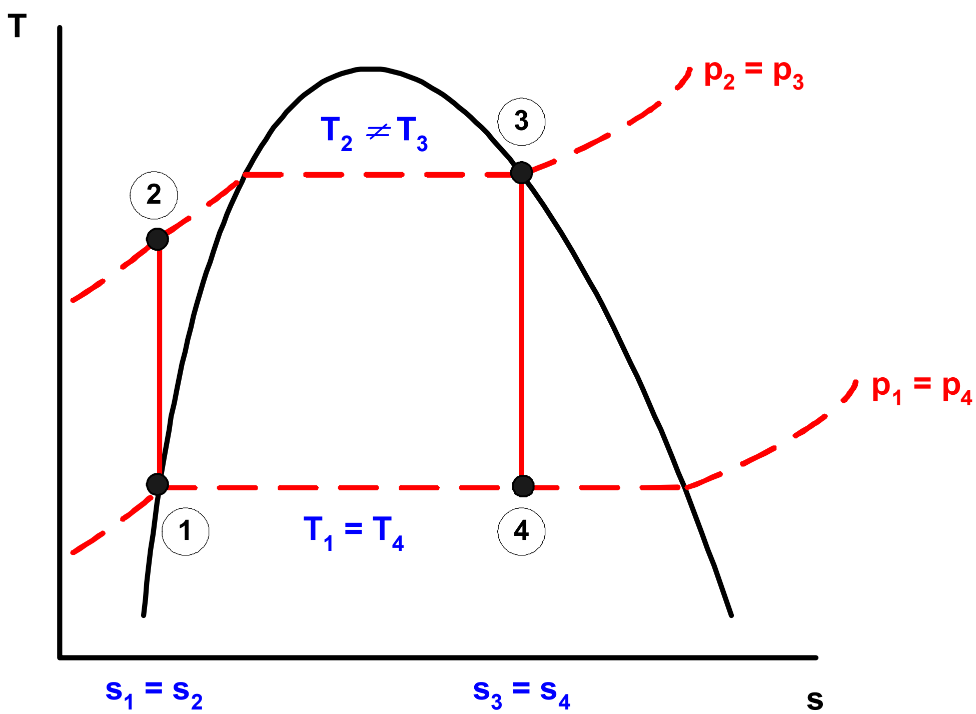

Critical Point
Saturated Liquid
Saturated Vapor
Know these five possible phases of water listed in red.
T
Subcooled Liquid
Superheated Vapor
Wet Vapor (Saturated Steam)
Saturation Dome
s


T
Boiling Pt
p_{HIGH}
Line of Constant Pressure
p_{LOW}
Line of Constant Pressure
s

Steam Plant Components



Ideal Rankine Cycle (w/o Superheat)



1 Saturated Liquid

3 Saturated Vapor

2 Subcooled Liquid

4 Wet Vapor (Saturated Steam)

Table 1: Saturated Steam (by Temperature)

Table 1. Saturated Steam: Temperature Table

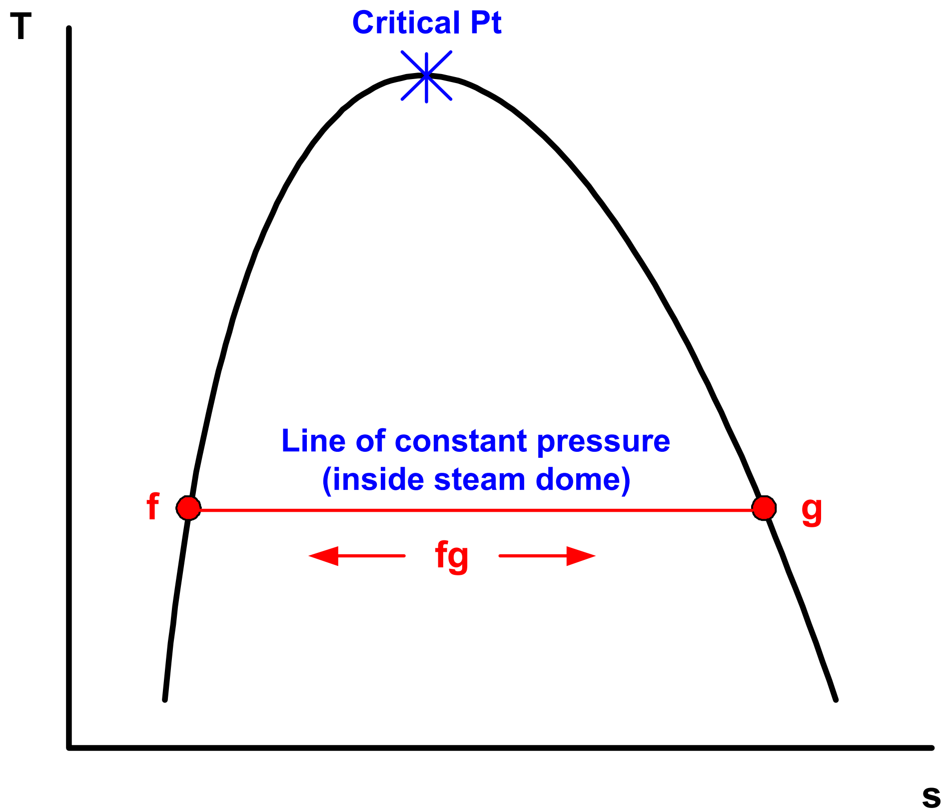
Temp Fahr t	Abs Press. Lb per Sq In. p	Specific Volume Sat. Liquid v_f	Evap v_{fg}	Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat. Liquid s_f	Evap s_{fg}	Sat. Vapor s_g	Temp Fahr t
32.0*	0.08859	0.016022	3304.7	3304.7	−0.0179	1075.5	1075.5	0.0000	2.1873	2.1873	**32.0***
34.0	0.09600	0.016021	3061.9	3061.9	1.996	1074.4	1076.4	0.0041	2.1762	2.1802	**34.0**
36.0	0.10395	0.016020	2839.0	2839.0	4.008	1073.2	1077.2	0.0081	2.1651	2.1732	**36.0**
38.0	0.11249	0.016019	2634.1	2634.2	6.018	1072.1	1078.1	0.0122	2.1541	2.1663	**38.0**
40.0	0.12163	0.016019	2445.8	2445.8	8.027	1071.0	1079.0	0.0162	2.1432	2.1594	**40.0**
42.0	0.13143	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	**42.0**
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	**44.0**
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	**46.0**
48.0	0.16514	0.016021	1830.0	1830.0	16.051	1066.4	1082.5	0.0321	2.1006	2.1327	**48.0**
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	**50.0**
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	**52.0**
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	**54.0**
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	**56.0**
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	**58.0**
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	**60.0**
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	**62.0**
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	**64.0**
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	**66.0**
68.0	0.33889	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	**68.0**
70.0	0.36292	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	**70.0**
72.0	0.38844	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	**72.0**
74.0	0.41550	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9708	2.0529	**74.0**
76.0	0.44420	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	**76.0**
78.0	0.47461	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	**78.0**
80.0	0.50683	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0359	**80.0**
82.0	0.54093	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	**82.0**
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	**84.0**
86.0	0.61518	0.016087	527.5	527.5	54.026	1045.0	1099.0	0.1043	1.9151	2.0193	**86.0**
88.0	0.65551	0.016093	496.8	496.8	56.022	1043.9	1099.9	0.1079	1.9060	2.0139	**88.0**
90.0	0.69813	0.016099	468.1	468.1	58.018	1042.7	1100.8	0.1115	1.8970	2.0086	**90.0**
92.0	0.74313	0.016105	441.3	441.3	60.014	1041.6	1101.6	0.1152	1.8881	2.0033	**92.0**
94.0	0.79062	0.016111	416.3	416.3	62.010	1040.5	1102.5	0.1188	1.8792	1.9980	**94.0**
96.0	0.84072	0.016117	392.8	392.9	64.006	1039.3	1103.3	0.1224	1.8704	1.9928	**96.0**
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	**98.0**

Table 2: Saturated Steam (by Pressure)

Table 2: Saturated Steam: Pressure Table

Abs Press. Lb/Sq In. p	Temp Fahr t	Specific Volume Sat. Liquid v_f	Evap v_{fg}	Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat. Liquid s_f	Evap s_{fg}	Sat. Vapor s_g	Abs Press. Lb/Sq In. p
0.08865	32.018	0.016022	3302.4	3302.4	0.0003	1075.5	1075.5	0.0000	2.1872	2.1872	**0.08865**
0.25	59.323	0.016032	1235.5	1235.5	27.382	1060.1	1087.4	0.0542	2.0425	2.0967	**0.25**
0.50	79.586	0.016071	641.5	641.5	47.623	1048.6	1096.3	0.0925	1.9446	2.0370	**0.50**
1.0	101.74	0.016136	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	**1.0**
5.0	162.24	0.016407	73.515	73.532	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	**5.0**
10.0	193.21	0.016592	38.404	38.420	161.26	982.1	1143.3	0.2836	1.5043	1.7879	**10.0**
14.696	212.00	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	**14.696**
15.0	213.03	0.016726	26.274	26.290	181.21	969.7	1150.9	0.3137	1.4415	1.7552	**15.0**
20.0	227.96	0.016834	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	**20.0**
30.0	250.34	0.017009	13.7266	13.7436	218.9	945.2	1164.1	0.3682	1.3313	1.6995	**30.0**
40.0	267.25	0.017151	10.4794	10.4965	236.1	933.6	1169.8	0.3921	1.2844	1.6765	**40.0**
50.0	281.02	0.017274	8.4967	8.5140	250.2	923.9	1174.1	0.4112	1.2474	1.6586	**50.0**
60.0	292.71	0.017383	7.1562	7.1736	262.2	915.4	1177.6	0.4273	1.2167	1.6440	**60.0**
70.0	302.93	0.017482	6.1875	6.2050	272.7	907.8	1180.6	0.4411	1.1905	1.6316	**70.0**
80.0	312.04	0.017573	5.4536	5.4711	282.1	900.9	1183.1	0.4534	1.1675	1.6208	**80.0**
90.0	320.28	0.017659	4.8779	4.8953	290.7	894.6	1185.3	0.4643	1.1470	1.6113	**90.0**
100.0	327.82	0.017740	4.4133	4.4310	298.5	888.6	1187.2	0.4743	1.1284	1.6027	**100.0**
110.0	334.79	0.01782	4.0306	4.0484	305.8	883.1	1188.9	0.4834	1.1115	1.5950	**110.0**
120.0	341.27	0.01789	3.7097	3.7275	312.6	877.8	1190.4	0.4919	1.0960	1.5879	**120.0**
130.0	347.33	0.01796	3.4364	3.4544	319.0	872.8	1191.7	0.4998	1.0815	1.5813	**130.0**
140.0	353.04	0.01803	3.2010	3.2190	325.0	868.0	1193.0	0.5071	1.0681	1.5752	**140.0**
150.0	358.43	0.01809	2.9958	3.0139	330.6	863.4	1194.1	0.5141	1.0554	1.5695	**150.0**
160.0	363.55	0.01815	2.8155	2.8336	336.1	859.0	1195.1	0.5206	1.0435	1.5641	**160.0**
170.0	368.42	0.01821	2.6556	2.6738	341.2	854.8	1196.0	0.5269	1.0322	1.5591	**170.0**
180.0	373.08	0.01827	2.5129	2.5312	346.2	850.7	1196.9	0.5328	1.0215	1.5543	**180.0**
190.0	377.53	0.01833	2.3847	2.4030	350.9	846.7	1197.6	0.5384	1.0113	1.5498	**190.0**
200.0	381.80	0.01839	2.2689	2.2873	355.5	842.8	1198.3	0.5438	1.0016	1.5454	**200.0**
210.0	385.91	0.01844	2.16373	2.18217	359.9	839.1	1199.0	0.5490	0.9923	1.5413	**210.0**
220.0	389.88	0.01850	2.06779	2.08629	364.2	835.4	1199.6	0.5540	0.9834	1.5374	**220.0**
230.0	393.70	0.01855	1.97991	1.99846	368.3	831.8	1200.1	0.5588	0.9748	1.5336	**230.0**
240.0	397.39	0.01860	1.89909	1.91769	372.3	828.4	1200.6	0.5634	0.9665	1.5299	**240.0**
250.0	400.97	0.01865	1.82452	1.84317	376.1	825.0	1201.1	0.5679	0.9585	1.5264	**250.0**
260.0	404.44	0.01870	1.75548	1.77418	379.9	821.6	1201.5	0.5722	0.9508	1.5230	**260.0**
270.0	407.80	0.01875	1.69137	1.71013	383.6	818.3	1201.9	0.5764	0.9433	1.5197	**270.0**
280.0	411.07	0.01880	1.63169	1.65049	387.1	815.1	1202.3	0.5805	0.9361	1.5166	**280.0**
290.0	414.25	0.01885	1.57597	1.59482	390.6	812.0	1202.6	0.5844	0.9291	1.5135	**290.0**

Property Values On or Inside the Steam Dome



*****Looking Up f and g Values from a T-s Diagram in the Steam Tables 1 and 2*****

f is any point <u>on the steam dome</u> left of the critical point – saturated liquid

g is any point <u>on the steam dome</u> right of the critical point – saturated vapor

f and g are both at the same pressure (and notice, both at the same temperature)

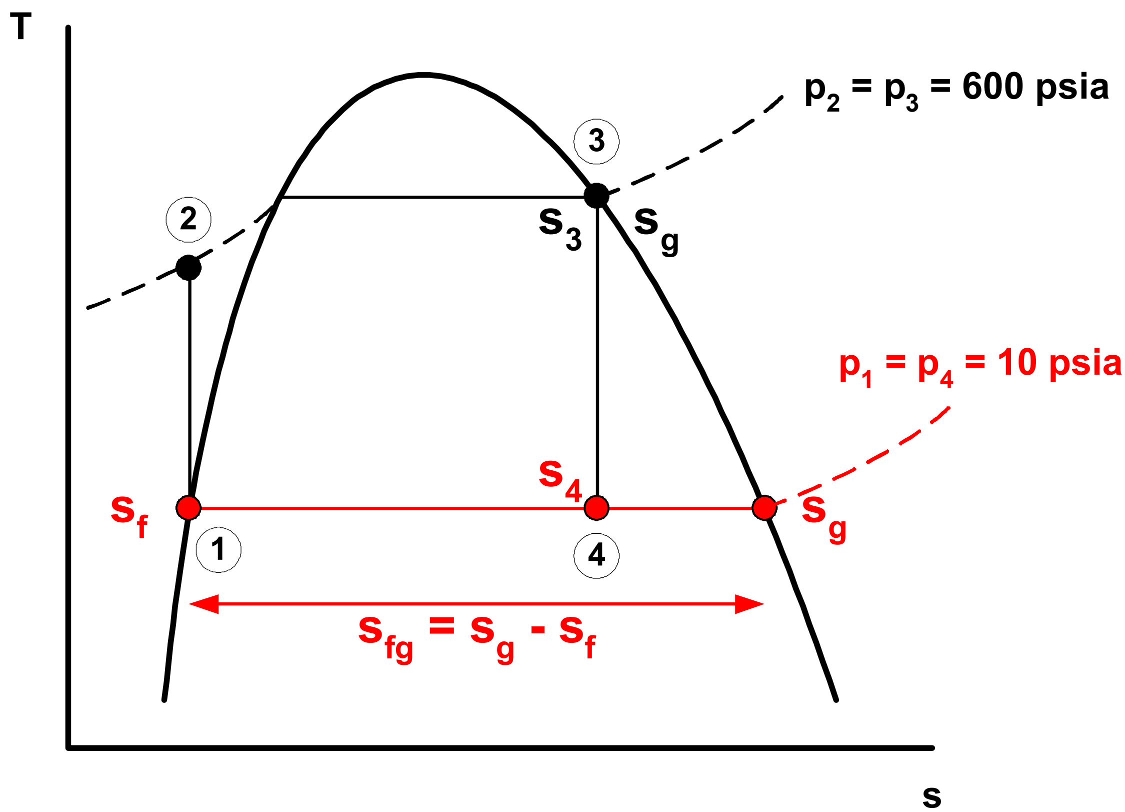
fg is the difference (“distance”) between value g and value f, for example:

$$s_g - s_f = s_{fg}$$
$$h_g - h_f = h_{fg}$$
$$n_g - n_f = n_{fg}$$

all values between f and g are in the saturated steam (wet vapor) phase

Steam Tables 1 and 2 are the only property tables you need to solve steam cycle problems <u>that do not have superheat</u>.

Steam Quality (x)



"Steam Quality" is denoted by the variable x. It represents the <u>percentage of vapor</u> (0% < x < 100%) in a WET VAPOR state point.

In the above T-s diagram, state point 4 is a wet vapor. This state point has a steam quality (x) given by:

$$s_f + (x_4)s_{fg} = s_4$$

Note that 3 → 4 is an isentropic expansion in the turbine (i.e. $s_3 = s_4$). So, s_3 is easily looked up as the s_g value for 600 psia in the steam tables.

Then we can look up s_f and s_{fg} values for 10 psia. Then solve for x:

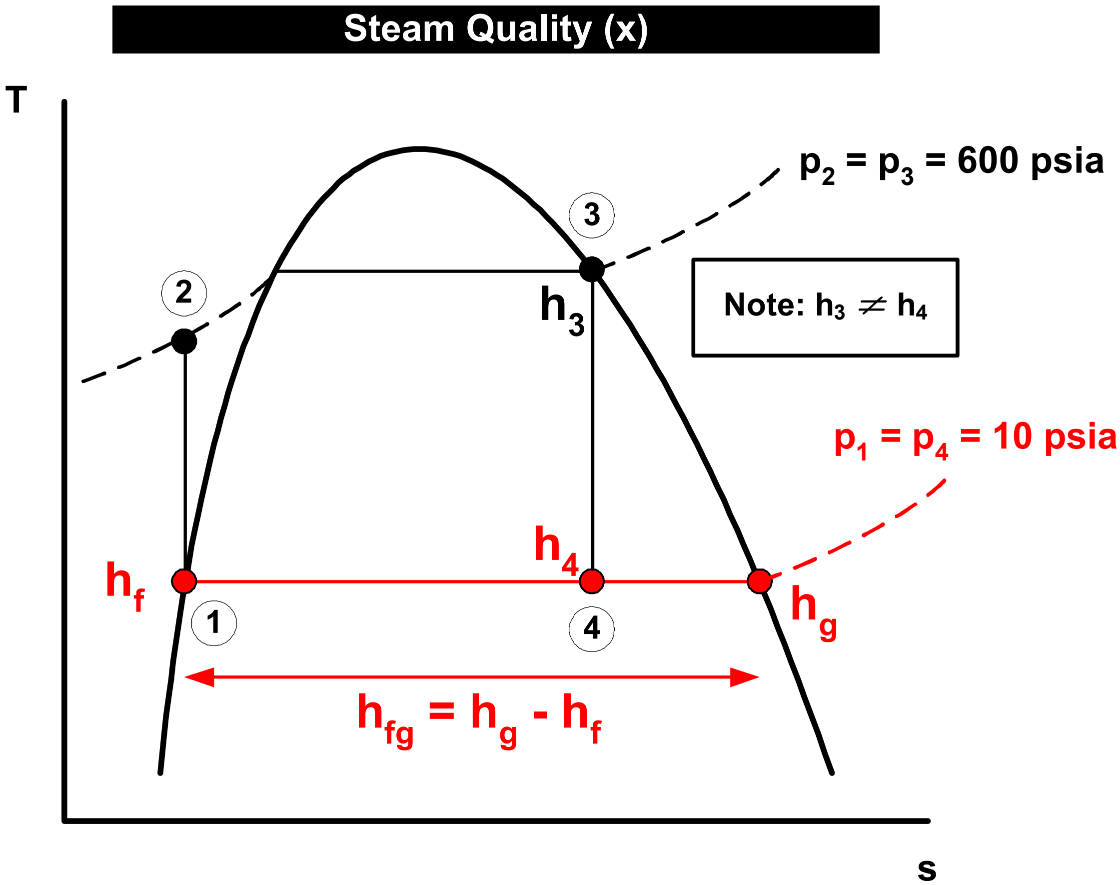
$$x_4 \quad \frac{s_4 \quad s_f}{s_{fg}} \; \% \text{ , where } s_4 = s_3$$

The counterpart variable to x is "Moisture Content" denoted by the variable m, and given by m = 100% – x. It indicates the <u>percentage of liquid</u> (0% < m < 100%) in a WET VAPOR state point. (Note: Use of m is required for the ***<u>Mollier Diagram</u>*, which is an h-s diagram**.)

The reason we solve for x is to find the value of h_4 using this same technique:

$$h_f + (x)h_{fg} = h_4$$

The above h_f and h_{fg} values for 10 psia are looked up in the steam tables.



Thus far we know how to solve for h_1, h_3, and h_4.

How about solving for h_2?

Process 1 → 2 is work in (pump work). This is given by:

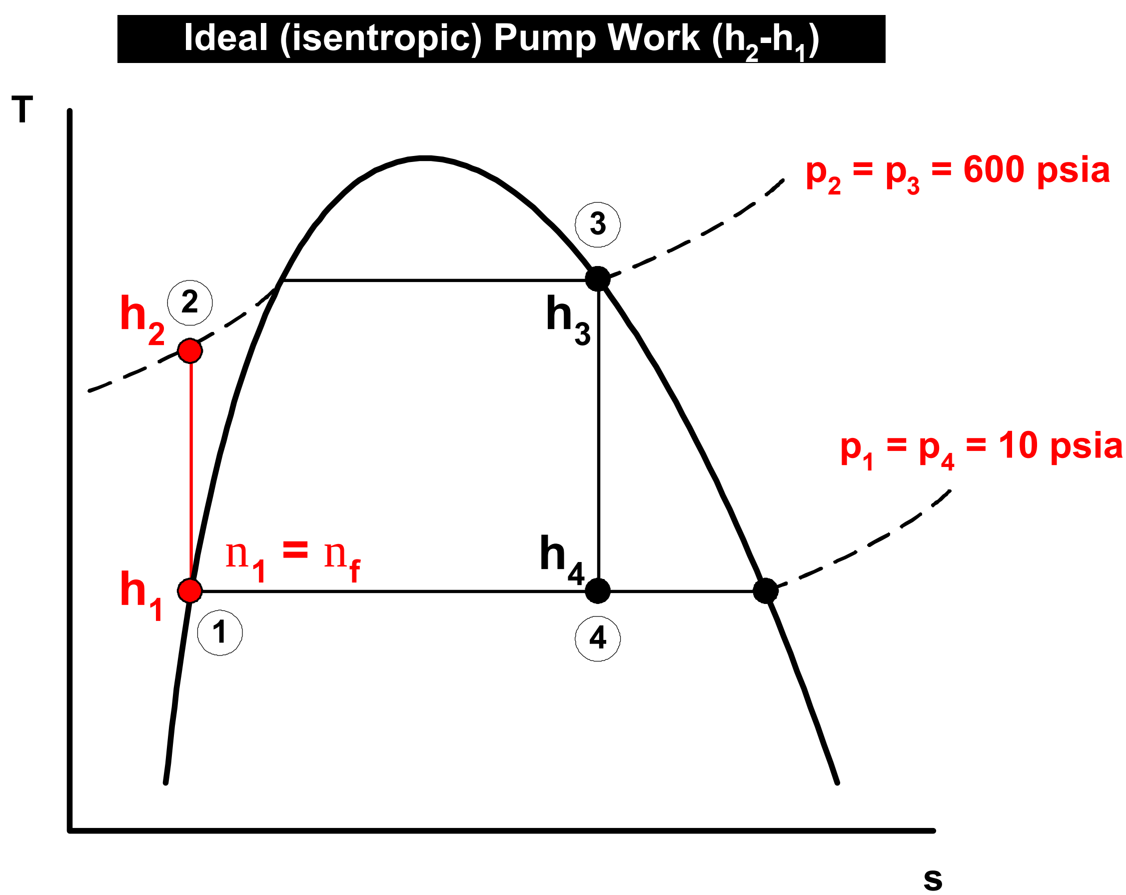
$$w_{12} = h_1 - h_2 \quad \underline{\text{or}} \quad w_{PUMP} = |w_{12}| = h_2 - h_1$$

In the ideal Rankine cycle, it is an <u>isentropic</u> process, which makes it an ideal pump (i.e. 100% component efficiency). However, we <u>will not</u> be setting $s_1 = s_2$ to solve for h_2, due to the complexities of using the subcooled liquid tables (which you do not have).

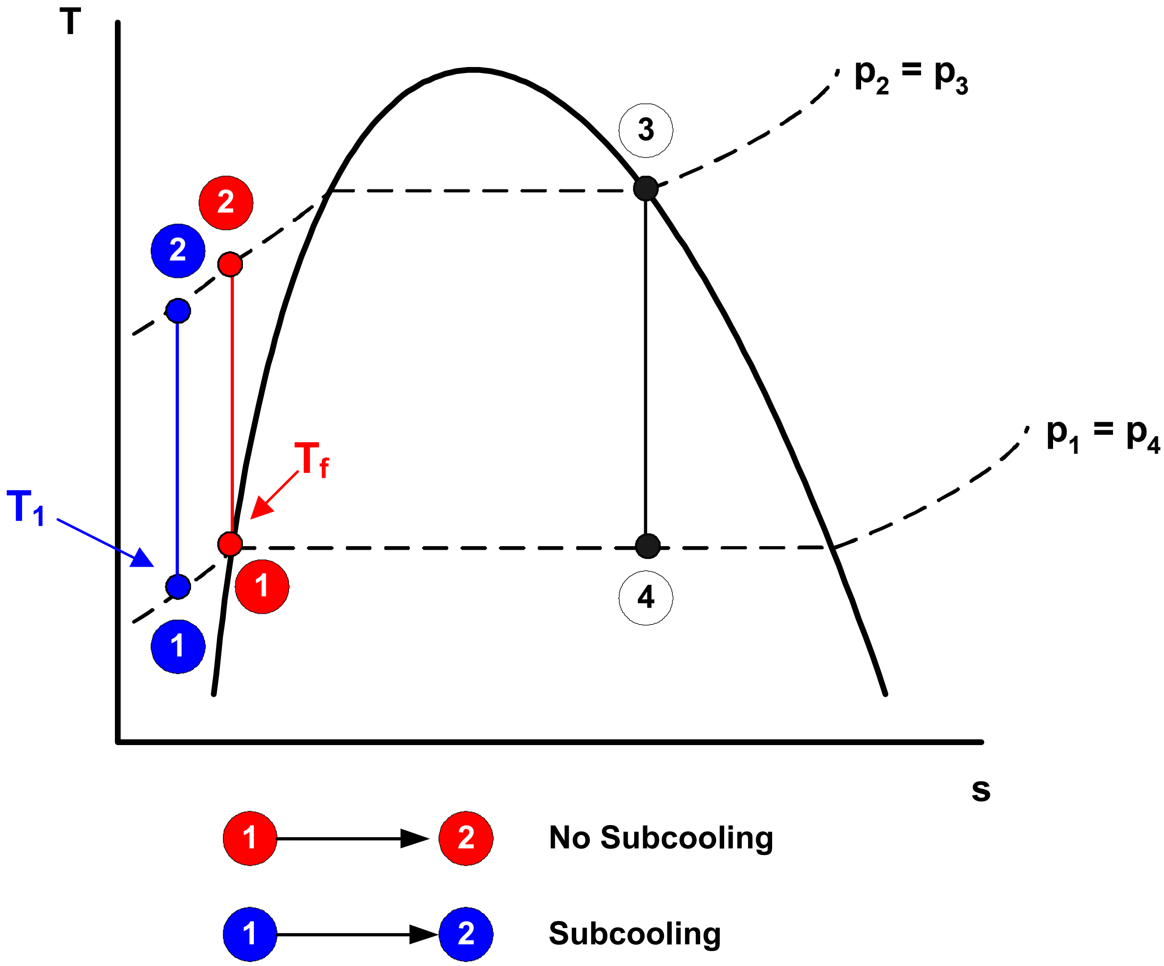
Remember that during 1 → 2, the water is in a pure liquid phase (saturated liquid or subcooled liquid) – that is, it is incompressible. "Incompressible" means that the water has a constant specific volume, ν (assume $\nu_1 = \nu_2 = \nu_f$ @ p_1). From a SFEE balance for an <u>isentropic</u> process, it is found that:

$$\boxed{w_{12} = \nu_1 (p_1 - p_2) = h_1 - h_2 \quad \underline{\text{or}} \quad w_{PUMP} = |w_{12}| = \nu_1 (p_2 - p_1) = h_2 - h_1}$$

Thus, the key to solving for h_2 is identifying ν_1 (simply look up $\nu_1 = \nu_f$ @ p_1) and identifying p_1 and p_2. (Note there is an exception in the case of *condenser subcooling* where ν_1 is looked up at $T_1 = T_f - T_{SUBCOOL}$ instead.)



Condenser Subcooling



In the case of ***condenser subcooling***, the water leaves the condenser at a temperature lower than the saturated liquid temperature (T_f) of the ideal Rankine cycle. HOWEVER, since the condenser is modeled as isobaric (i.e. $p_1 = p_4$), the new state point 1 is still along the constant pressure line, just in the subcooled liquid region at a LOWER temperature than T_f.

Effect of subcooling:

If condenser subcooling occurs (usually given as something like "the condensate leaves the condenser with 7°F subcooling"), then ν_1 (and h_1) MUST NOT be looked up at pressure p_1 in the steam table. Instead **ν_1 (and h_1) must be looked up at the temperature $T_1 = T_f$ (@p1) – $T_{SUBCOOL}$**. Since you do not have subcooled liquid tables, you will approximate by using the value ν_f (@T_1) = ν_1.

Summary of enthalpy values (<u>ideal</u> Rankine cycle):

☑ $h_1 = h_f$ (@ $p_1 = p_4$ pressure in steam tables), except subcooling

☑ $h2 = h1 + \nu_1 (p_2 - p_1) = h1 + w_{PUMP}$

☑ $h_3 = h_g$ (@ $p_2 = p_3$ pressure in steam tables)

☑ $h_4 = h_f + (x)\, h_{fg}$ (h_f and h_{fg} are @ $p_1 = p_4$ pressure in steam tables)

NOTES:

(1) <u>DO NOT USE the pump technique for the turbine enthalpies</u>. That is:

$$h_3 \neq h_4 + \nu_4 (p_3 - p_4)$$

because, in the turbine, the water IS NOT an incompressible liquid!

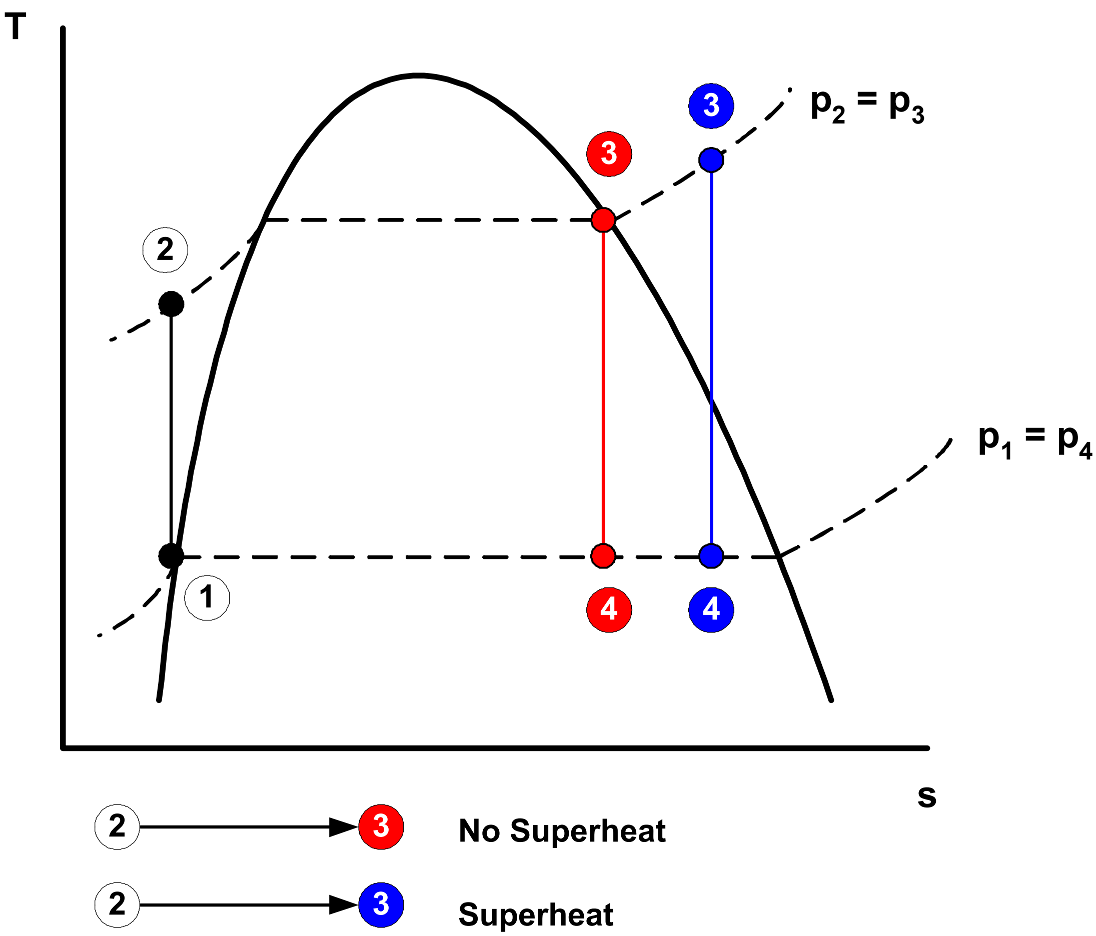
(2) Remember pump work in the form "$\nu_1 (p_2 - p_1)$" does not directly work out to units of [Btu/lb_m], so use appropriate conversion factors.

(3) $\nu_1 = \nu_f$ will NOT be looked up at $p_1 = p_4$ IF there is *condenser subcooling*. Use ν_1 @ T_1 instead, where $T_1 = T_f$ (@p1) – $T_{SUBCOOL}$.

FOR ANALYSIS OF A STEAM CYCLE, a state point properties table will be useful. For the <u>ideal</u> Rankine cycle, we have 4 state points, thus:

	1	2	3	4
p [psia]				
T [°F]				
h [Btu/lbm]				
s [Btu/lb_m°R]				
ν [ft^3/lb_m]				

Superheating



Superheat is the result of the boiler supplying enough heat ($q_s = h_3 - h_2$) such that state point 3 (exit of the boiler) exceeds the saturation temperature ($T_f = T_g$) of the water at boiler pressure ($p_2 = p_3$). In other words, the steam leaves the boiler in a superheated vapor phase.

In finding h_3, the only difference now is that we must use the superheated steam portion (table 3) of the steam tables. Without superheat, previously, we would use the saturated steam (table 1 or table 2) portion of the steam tables.

Table 3: Superheated Steam (by Pressure)

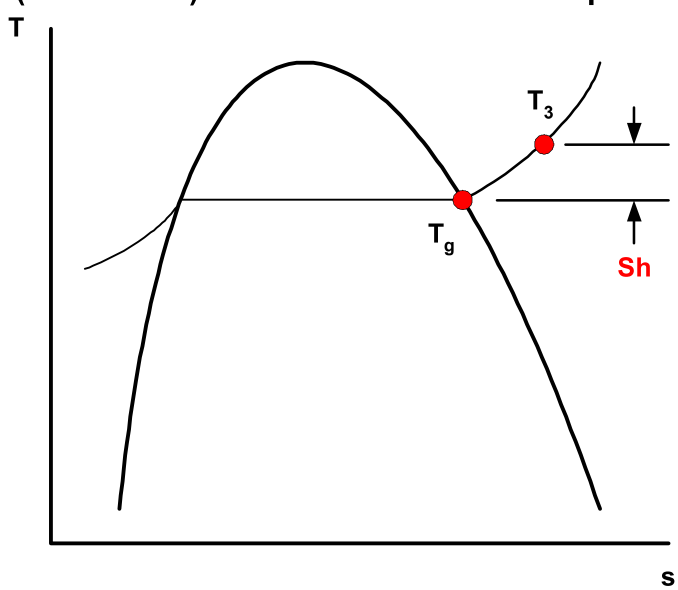
Table 3. Superheated Steam

Abs Press. Lb/Sq In. (Sat. Temp)		Sat. Water	Sat. Steam	Temperature — Degrees Fahrenheit 200	250	300	350	400	450	500	600	700	800	900	1000	1100	1200
1 (101.74)	Sh			98.26	148.26	198.26	248.26	298.26	348.26	398.26	498.26	598.26	698.26	798.26	898.26	998.26	1098.26
	v	0.01614	333.6	392.5	422.4	452.3	482.1	511.9	541.7	571.5	631.1	690.7	750.3	809.8	869.4	929.0	988.6
	h	69.73	1105.8	1150.2	1172.9	1195.7	1218.7	1241.8	1265.1	1288.6	1336.1	1384.5	1433.7	1483.8	1534.9	1586.8	1639.7
	s	0.1326	1.9781	2.0509	2.0841	2.1152	2.1445	2.1722	2.1985	2.2237	2.2708	2.3144	2.3551	2.3934	2.4296	2.4640	2.4969
5 (162.24)	Sh			37.76	87.76	137.76	187.76	237.76	287.76	337.76	437.76	537.76	637.76	737.76	837.76	937.76	1037.76
	v	0.01641	73.53	78.14	84.21	90.24	96.25	102.24	108.23	114.21	126.15	138.08	150.01	161.94	173.86	185.78	197.70
	h	130.20	1131.1	1148.6	1171.7	1194.8	1218.0	1241.3	1264.7	1288.2	1335.9	1384.3	1433.6	1483.7	1534.7	1586.7	1639.6
	s	0.2349	1.8443	1.8716	1.9054	1.9369	1.9664	1.9943	2.0208	2.0460	2.0932	2.1369	2.1776	2.2159	2.2521	2.2866	2.3194
10 (193.21)	Sh			6.79	56.79	106.79	156.79	206.79	256.79	306.79	406.79	506.79	606.79	706.79	806.79	906.79	1006.79
	v	0.01659	38.42	38.84	41.93	44.98	48.02	51.03	54.04	57.04	63.03	69.00	74.98	80.94	86.91	92.87	98.84
	h	161.26	1143.3	1146.6	1170.2	1193.7	1217.1	1240.6	1264.1	1287.8	1335.5	1384.0	1433.4	1483.5	1534.6	1586.6	1639.5
	s	0.2836	1.7879	1.7928	1.8273	1.8593	1.8892	1.9173	1.9439	1.9692	2.0166	2.0603	2.1011	2.1394	2.1757	2.2101	2.2430
14.696 (212.00)	Sh				38.00	88.00	138.00	188.00	238.00	288.00	388.00	488.00	588.00	688.00	788.00	888.00	988.00
	v	.0167	26.799		28.42	30.52	32.60	34.67	36.72	38.77	42.86	46.93	51.00	55.06	59.13	63.19	67.25
	h	180.17	1150.5		1168.8	1192.6	1216.3	1239.9	1263.6	1287.4	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4
	s	.3121	1.7568		1.7833	1.8158	1.8459	1.8743	1.9010	1.9265	1.9739	2.0177	2.0585	2.0969	2.1332	2.1676	2.2005
15 (213.03)	Sh				36.97	86.97	136.97	186.97	236.97	286.97	386.97	486.97	586.97	686.97	786.97	886.97	986.97
	v	0.01673	26.290		27.837	29.899	31.939	33.963	35.977	37.985	41.986	45.978	49.964	53.946	57.926	61.905	65.882
	h	181.21	1150.9		1168.7	1192.5	1216.2	1239.9	1263.6	1287.3	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4
	s	0.3137	1.7552		1.7809	1.8134	1.8437	1.8720	1.8988	1.9242	1.9717	2.0155	2.0563	2.0946	2.1309	2.1653	2.1982
20 (227.96)	Sh				22.04	72.04	122.04	172.04	222.04	272.04	372.04	472.04	572.04	672.04	772.04	872.04	972.04
	v	0.01683	20.087		20.788	22.356	23.900	25.428	26.946	28.457	31.466	34.465	37.458	40.447	43.435	46.420	49.405
	h	196.27	1156.3		1167.1	1191.4	1215.4	1239.2	1263.0	1286.9	1334.9	1383.5	1432.9	1483.2	1534.3	1586.3	1639.3
	s	0.3358	1.7320		1.7475	1.7805	1.8111	1.8397	1.8666	1.8921	1.9397	1.9836	2.0244	2.0628	2.0991	2.1336	2.1665
25 (240.07)	Sh				9.93	59.93	109.93	159.93	209.93	259.93	359.93	459.93	559.93	659.93	759.93	859.93	959.93
	v	0.01693	16.301		16.558	17.829	19.076	20.307	21.527	22.740	25.153	27.557	29.954	32.348	34.740	37.130	39.518
	h	208.52	1160.6		1165.6	1190.2	1214.5	1238.5	1262.5	1286.4	1334.6	1383.3	1432.7	1483.0	1534.2	1586.2	1639.2
	s	0.3535	1.7141		1.7212	1.7547	1.7856	1.8145	1.8415	1.8672	1.9149	1.9588	1.9997	2.0381	2.0744	2.1089	2.1418
30 (250.34)	Sh					49.66	99.66	149.66	199.66	249.66	349.66	449.66	549.66	649.66	749.66	849.66	949.66
	v	0.01701	13.744			14.810	15.859	16.892	17.914	18.929	20.945	22.951	24.952	26.949	28.943	30.936	32.927
	h	218.93	1164.1			1189.0	1213.6	1237.8	1261.9	1286.0	1334.2	1383.0	1432.5	1482.8	1534.0	1586.1	1639.0
	s	0.3682	1.6995			1.7334	1.7647	1.7937	1.8210	1.8467	1.8946	1.9386	1.9795	2.0179	2.0543	2.0888	2.1217

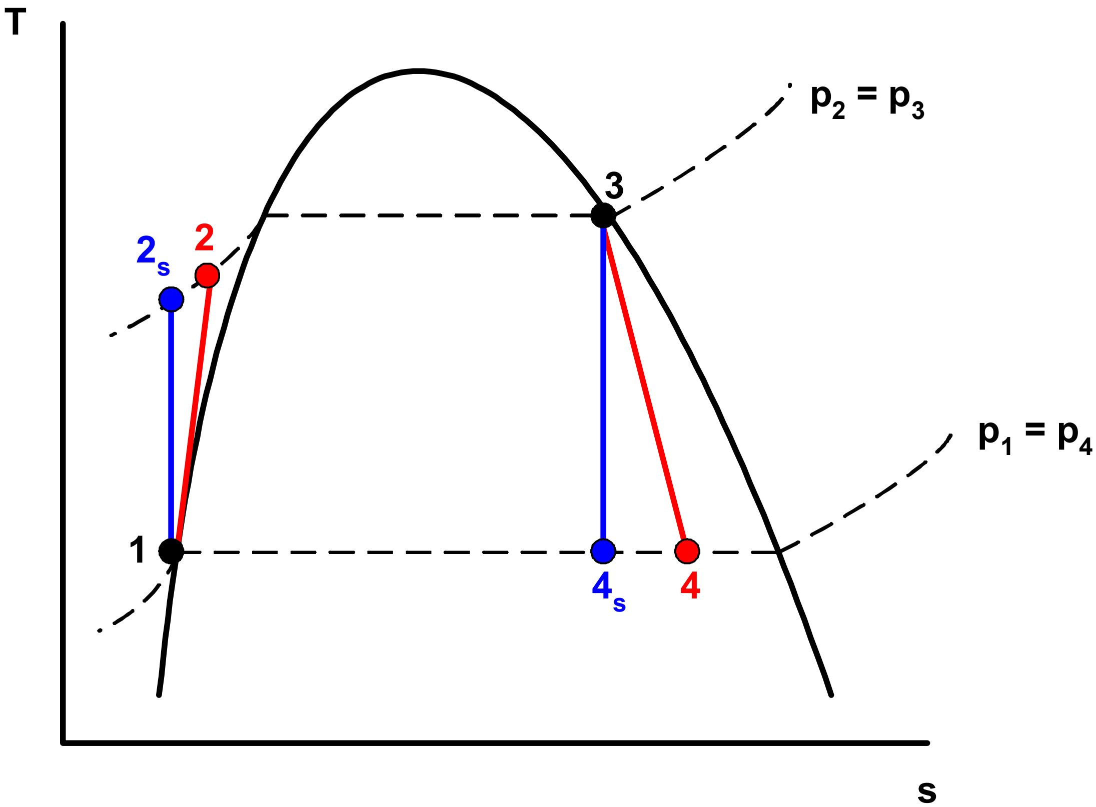
Table 3 has a different layout than Tables 1 and 2.

Generally, you will look up property values by using the <u>boiler pressure</u> as your entering argument. Then use the <u>maximum boiler temperature</u> as your cross-reference argument to find n, h, or s.

What is Sh? This is the "degrees of superheat." In other words, this is the number of degrees (Fahrenheit) above the saturation temperature T_g.



Pump and Turbine Efficiencies



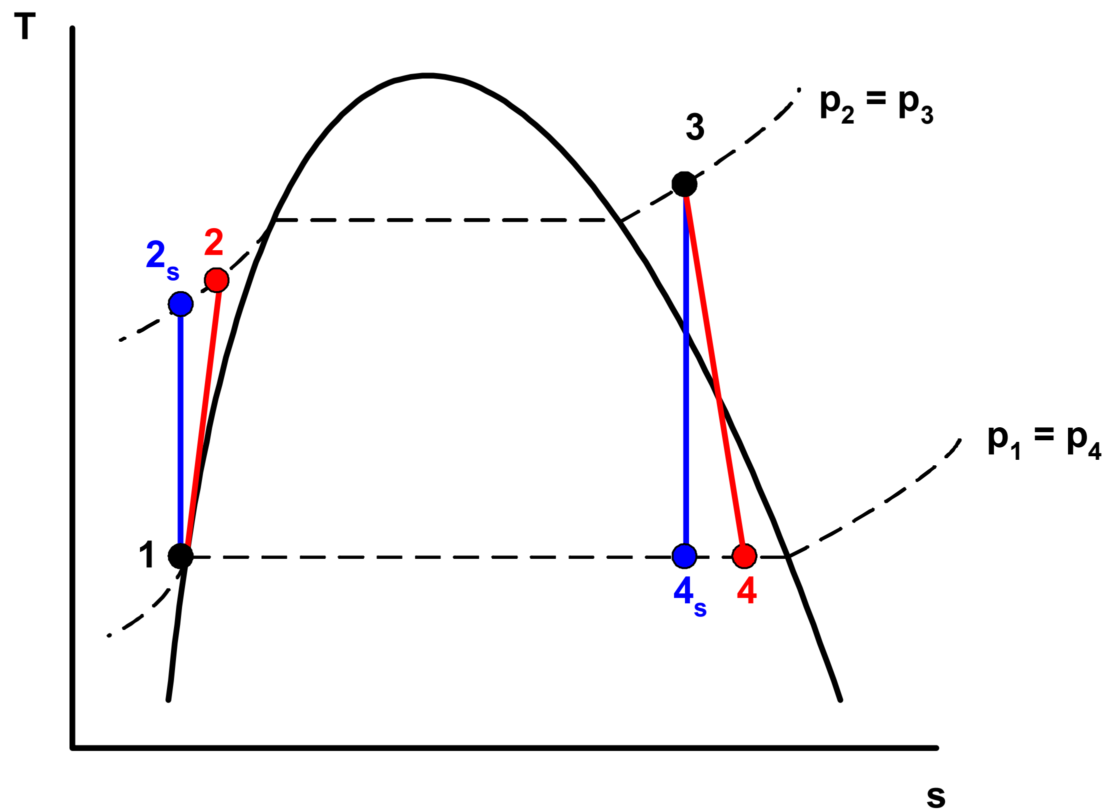
Component efficiencies for the pump and turbine are similar to that of the compressor and turbine in the gas turbine engine:

$$\eta_{PUMP} = \frac{h_{2s} - h_1}{h_2 - h_1} \quad \underline{\textbf{and}} \quad \eta_{TURB} = \frac{h_3 - h_4}{h_3 - h_{4s}}$$

The component efficiency of the boiler is very similar to the component efficiency of the combustion chamber in the GT engine:

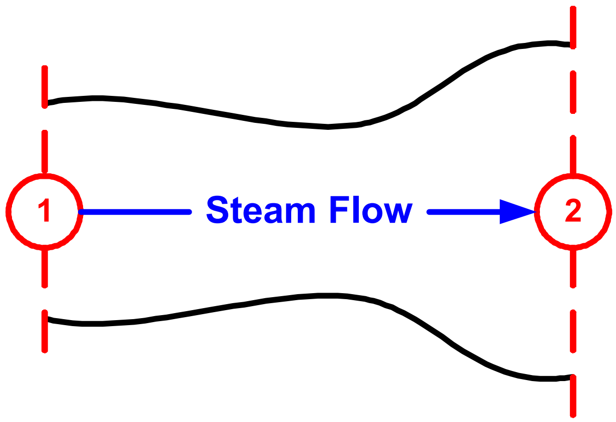
$$\eta_{BOILER} = \frac{\dot{m}_{STM}(h_3 - h_2)}{\dot{m}_{FUEL}(HHV)}$$

Pump and Turbine Efficiencies (w/ superheat)



Note: Look at h_4 and h_{4s}. Inside the steam dome both points lie on the constant pressure line $p_1 = p_4$. It may not be apparent inside the steam dome, but we find that $(h_3 - h_4) < (h_3 - h_{4s})$ because $h_{4s} < h_4$.

Nozzle



Nozzles are used inside the turbine to produce a high velocity steam that strikes the turbine blades (which in turns causes turbine rotation to produce shaft output power).

Remember that the working fluid, as it enters the turbine (i.e. exits the boiler), is now a <u>compressible</u> saturated vapor or superheated vapor. If a nozzle is designed properly, it is possible to increase the velocity V (of a compressible fluid) as the nozzle cross-section area A increases. So we find for the turbine nozzle:

$$A_2 > A_1 \quad \underline{\text{and}} \quad V_2 > V_1$$

It is useful in turbine design to analyze the SFEE properties of the turbine nozzle:

$$\left(\frac{g}{g_c}\right)z_1 + \left(\frac{1}{2g_c}\right)V_1^2 + h_1 + q_{12} = \left(\frac{g}{g_c}\right)z_2 + \left(\frac{1}{2g_c}\right)V_2^2 + h_2 + w_{12}$$

By assuming an adiabatic ($q_{12} = 0$) nozzle design with negligible height difference ($z_1 = z_2$) and no mechanical work done ($w_{12} = 0$), we are left with the following:

$$V_2^2 - V_1^2 = 2g_c\left(h_1 - h_2\right)$$

NOTES

(1) DO NOT confuse the above h_1 and h_2 for the enthalpies at the entrance and exit of the pump. These are just the enthalpies at the entrance (1) and exit (2) of the nozzle.

(2) Usually, but not always, velocity V_1 is negligible compared to velocity V_2. You must carefully read the problem statement to determine if you can neglect V_1.